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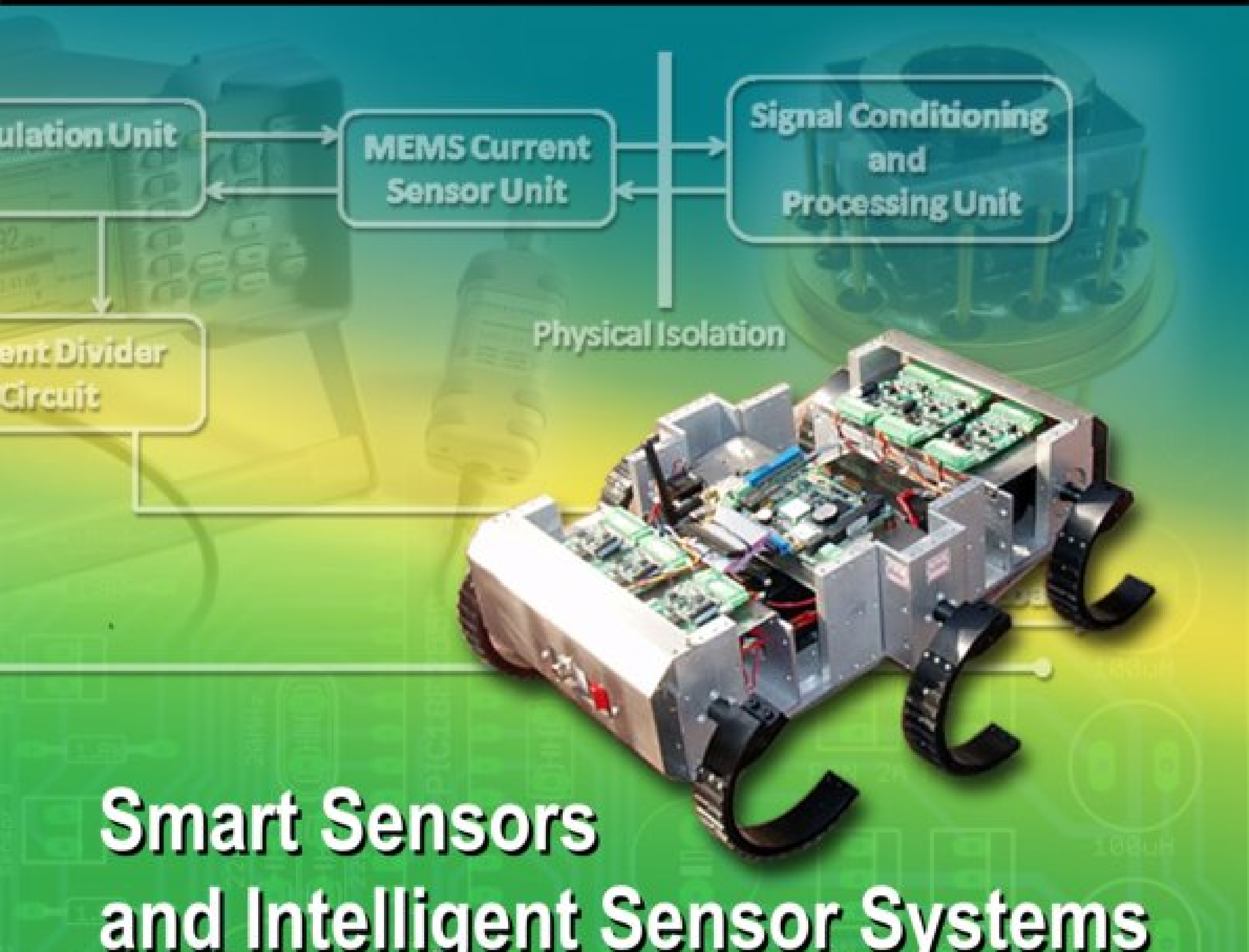

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Application of Frequency-Domain Integral Algorithm to the Processing of Sport Signals Based on MTi Sensor

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Abstract: MTi sensor is a new kind of MEMS sensor that can output high precision values of three dimensional acceleration and angular velocity. The acceleration signal of human body is low frequency signal. There exist some noises of low frequency in the data acquired by MTi sensor. Integration is sensitive to low frequency components, thus such noises have great impact on the integration result. Over time the cumulative small low-frequency noises will be amplified. The lower the frequency is, the more obvious will the impact be. Therefore, time-domain integration has large errors. Undertaking this task in frequency domain by Fourier transform can avoid such amplification. In this paper, the frequency-domain integral algorithm can also filter out some low frequency noises thus improve the integration accuracy by selecting appropriate cut-off frequency. Successful application to simulation and real sport signals show that the algorism is effective. *Copyright © 2012 IFSA.*

Keywords: MTi, Attitude sensor, Acceleration, Frequency-domain integration, FFT.

1. Introduction

At present, the analysis for sport signals is mostly based on video analysis system in the sports world. Its analytic process includes obtaining sports video images and then tracking the video images to acquire the information and the kinematic parameters of human body. At last it gets visual data and curves. The analysis process is based mainly on the experience and observation of the human eyes, which apparently has certain limitations and shortcomings [1-4]. The system is also expensive and not conducive for promotion. So it's not used widely. The main disadvantage of the video analysis system is that the system could not analyze instantaneously, therefore, it could not facilitate training on the spot.

To overcome this disadvantage, we use an information acquisition system based on MTi sensor produced by Xsens Company. It's shown in Fig. 1. The system is made up of four modules shown in Fig. 2, which are Remote Control module, Acquisition and Storage module, Receiver module and Sync module. The MTi sensor can output high-precision parameters of three-dimensional acceleration and angular velocity [5], thus we can get other kinematic parameters such as velocity, angle and angular acceleration through the integral, differential method.

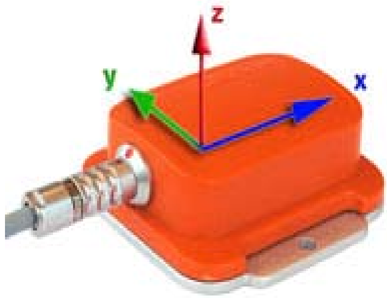

Fig. 1. MTi sensor.

Fig. 2. Four modules of the system.

However, direct integration of the acceleration signal is not practical as the output signal contains low-frequency noises. Their origins are various: the DC component of gravity g; noises produced when A/D transforming; zero drift [7]; the sensor has certain noises when measuring [8-9]. These low-frequency noises are hard to remove and will be amplified as the time increases. So it's necessary to adopt other integration means. And integration in the frequency domain shows effectiveness in certain sport signals.

2. Theory of Frequency-Domain Integration

There are mainly two steps in the frequency-domain integral algorithm. The first one is transforming the signals by Fast Fourier Transform (FFT). And time-domain integration and frequency-domain frequency integration have corresponding relation as following formulas [6].

$$V = \frac{A}{iw} \tag{1}$$

$$X = -\frac{A}{w^2} \tag{2}$$

A, V, X are respectively the Fourier coefficient of weight for acceleration, speed and displacement. From the above formulas it can be seen that the integral exchange of sine and cosine coefficient (the swap of the phase of acceleration, speed and displacement) avoid accumulation and amplification in the time-domain integration of tiny noises [6].

The second step is setting suitable cut-off frequency to remove the low-frequency noises. The noises with lower frequency then are eliminated from the useful information.

3. Simulation

Apply the algorithm to a sin signal $x = \sin(2\times\pi\times3\times t)$. Its frequency is 3 Hz and the theoretic integration result for it is $-\cos(6\times\pi\times t)\div(6\times\pi)$. When the cut-off frequency is set to low, such as 0.1 Hz, the integral wave will become distorted. And when set it 1 Hz above, the wave is ideal. Fig. 3 is the integral result diagram while lower cut-off frequency is set 0.1 and 1 Hz.

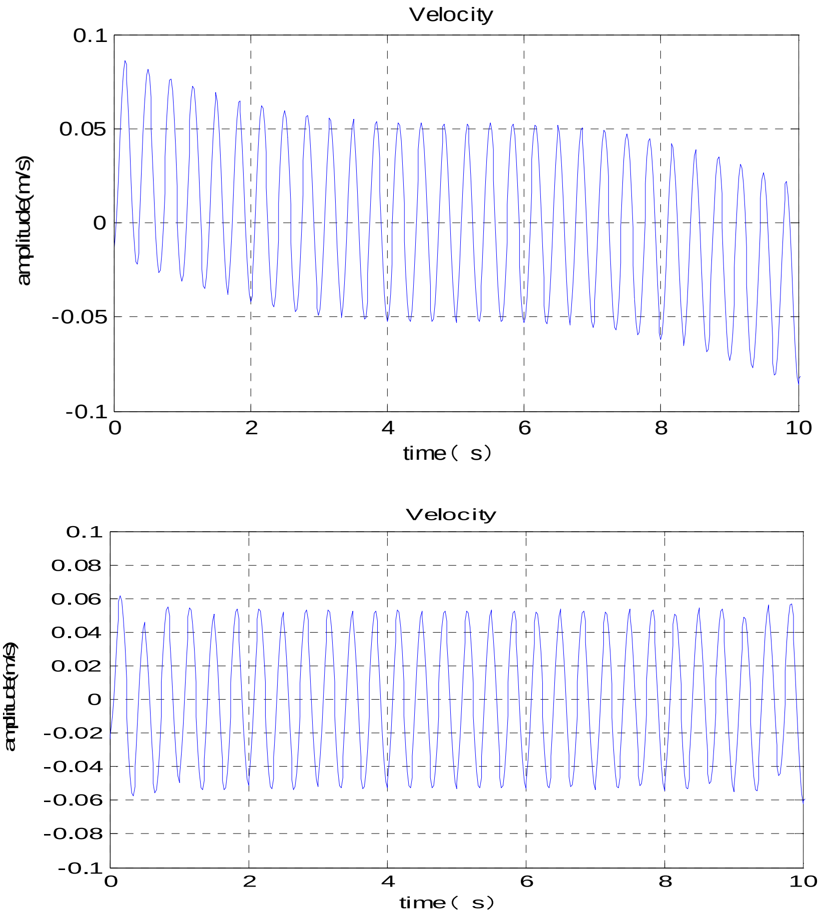

Fig. 3. Simulation results.

The reason for the difference is that after FFT the signal component lower than 3 Hz is not zero. It comes from the spectrum leakage of limited data and cannot be avoided [8]. When doing the frequency domain integration, this component will multiply $\frac{1}{iw}$, when this w is very small, the result will be considerable, thus brings a obvious peak in the wave. So it's important to choose suitable cut-off frequency to remove such component.

4. Application in Sport Signals

4.1. Running Sport

An athlete wore the sensors and took coming-and-going run in a certain range. Then we undertook the acceleration integration. Figs. 4 - 6 are the velocity curves of three dimensions: heading direction, lateral direction and perpendicular to the ground direction.

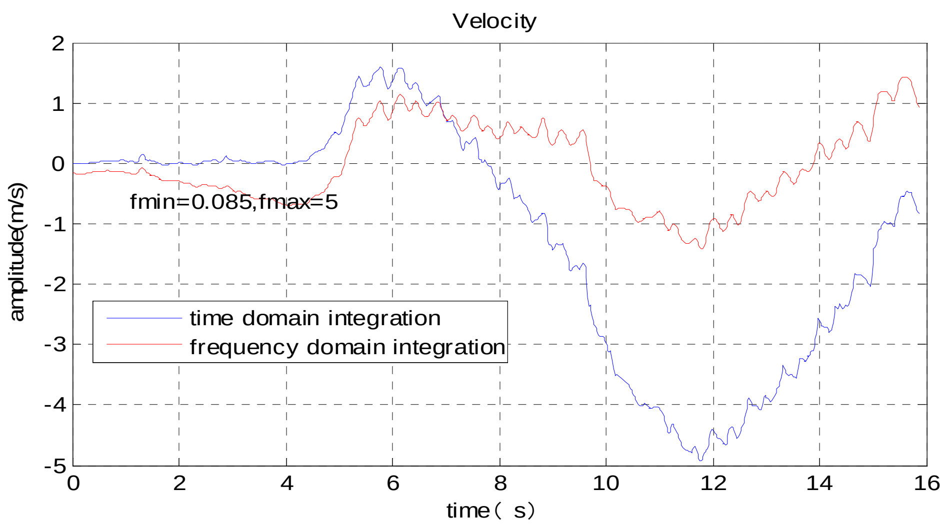

Fig. 4. Heading direction.

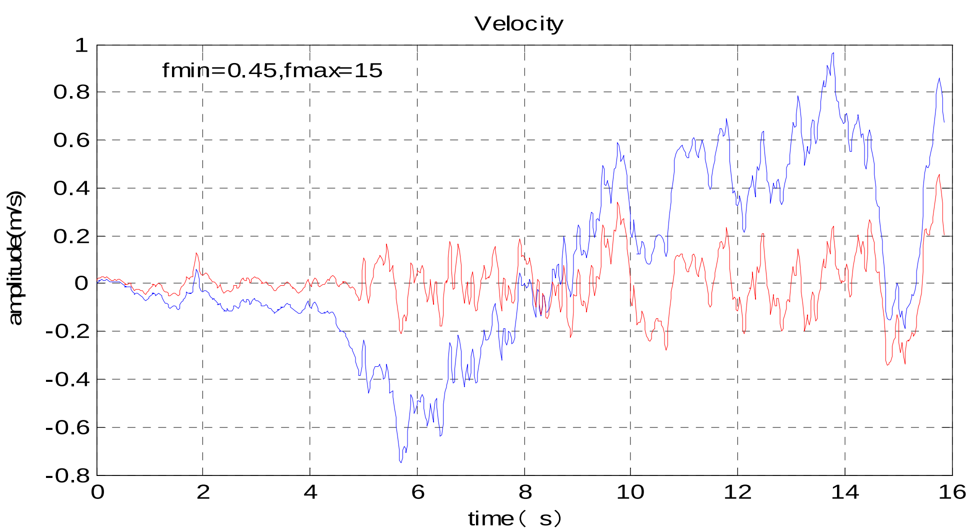

Fig. 5. Lateral direction.

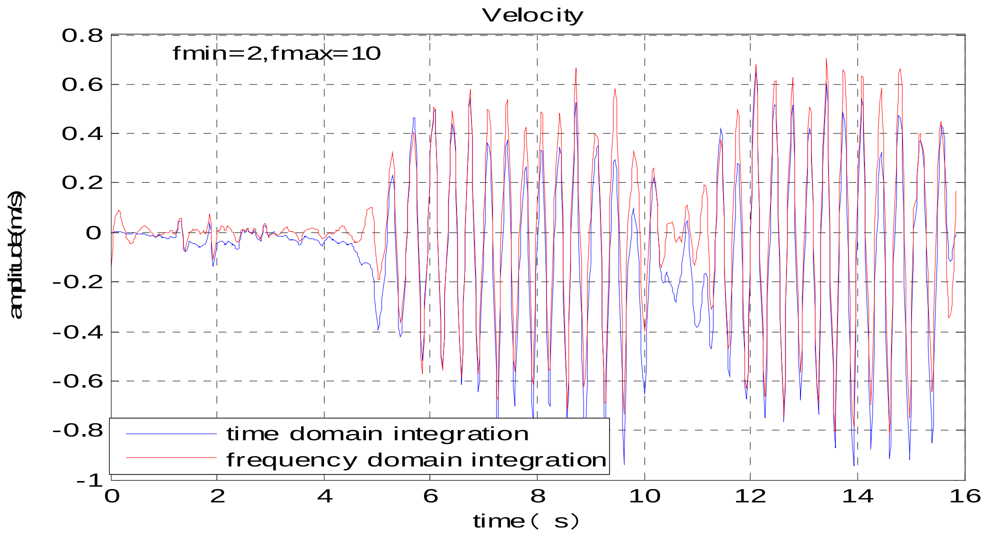

Fig. 6. Perpendicular to the ground direction.

The results show that at three directions the frequency domain integration algorithm is effective on dealing with the running sport signal.

4.2. Back-Style High Jump

As the athlete didn't ran toward a direct line, so I calculated velocity of the forward direction instead of the heading direction. Fig. 7 and Fig. 8 show the velocity curves in two directions.

From the sport curves, we can infer that the athlete started accelerating at 7 s and jumped over the baluster at 11 s. The frequency domain integration also gets better results than direct integration in time domain. It inhibits the influence of low frequency noises.

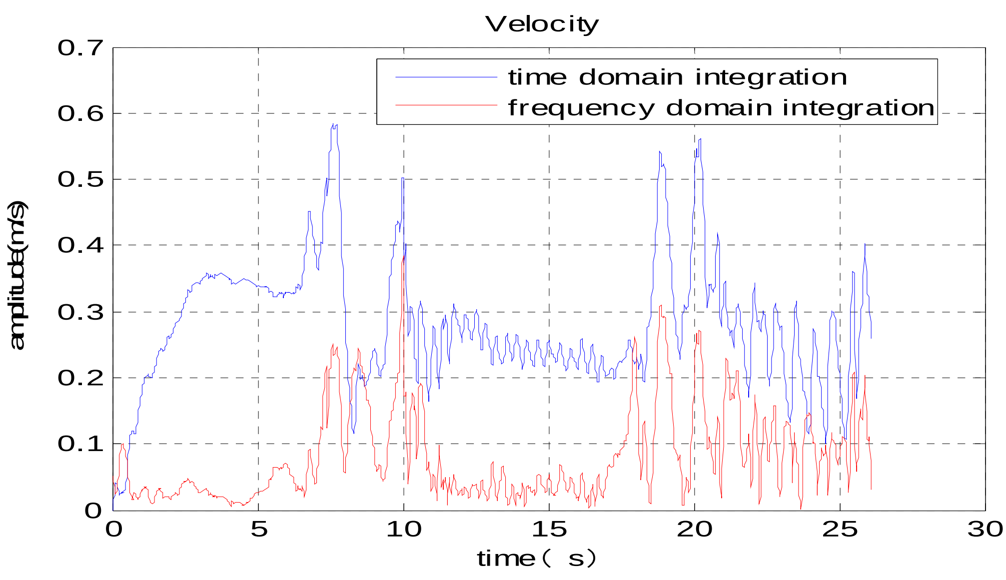

Fig. 7. Forward direction.

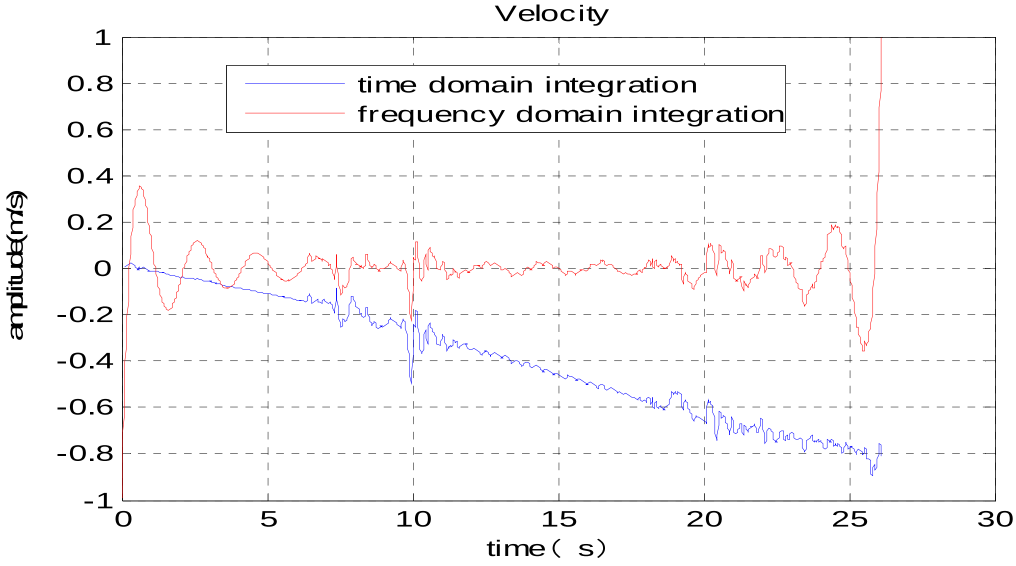

Fig. 8. Perpendicular to the ground direction.

4.3. U-Shaped Slot Skiing

The athlete skied forward in a spiral way at a u-shaped slot as shown in Fig. 9. So theoretically the velocity curve in the perpendicular to the ground direction should be fluctuation symmetrical. The direct integration curve has a trend to increase. After filtering some low-frequency noises, the result is much better. It can be seen from Fig. 10.

Fig. 9. U-Shaped Slot Skiing.

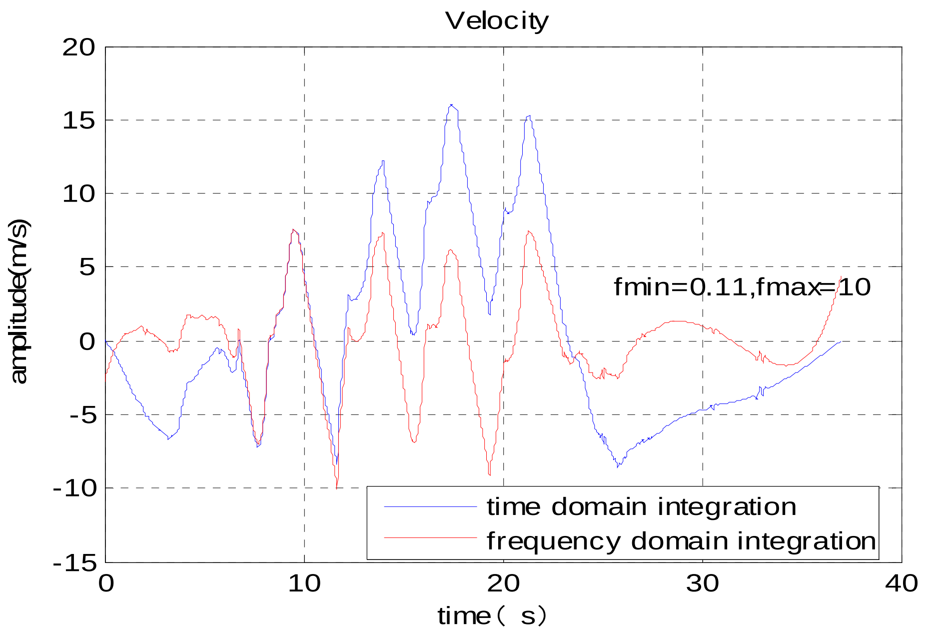

Fig. 10. Perpendicular to the ground direction.

It's obvious that the improved algorithm inhibits the influence of low frequency noises.

5. Limitations

In equations (1), (2), the denominator contains *w*, so the result relies heavily on the *w* when *w* is small [7]. FFT brings spectrum leakage and set appropriate cut-off frequency is important.

6. Conclusions

In this paper, the author introduces an information acquisition system based on MTi sensor, which can obtain three dimensional acceleration and angular velocity parameters of motion directly. From these parameters, the coaches can guide the athlete training on spot.

Then the author applies a popular method in the vibration field to acquired sport signals to improve the integration accuracy. The results show that the method can effectively remove DC component and low frequency noise to improve integration results. This method is simple and the effectiveness is obvious. Although it has some limitations, it can yet be regarded as a good method on low-frequency signal integration.

Acknowledgements

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- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
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